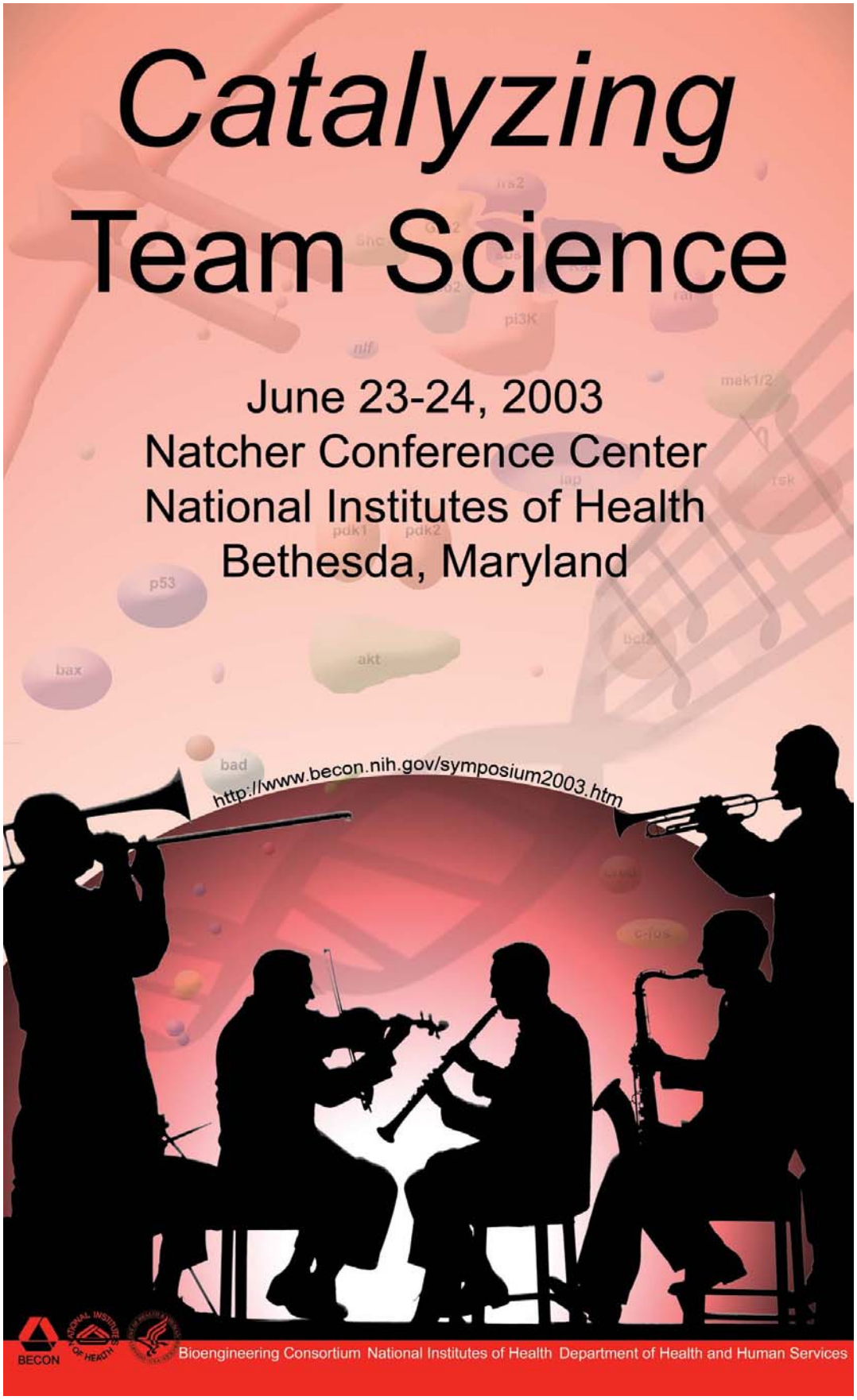
Catalyzing
Team Science
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BECON
Bioengineering Consortium National Institutes of Health Department of Health and Human Services

Catalyzing Team Science

Report from The 2003 BECON Symposium

Introduction

Many areas of modern biomedical research and, in particular, translations of complex discoveries into useful clinical applications increasingly require multi-disciplinary and inter-disciplinary teams. The past decade presented us with identification of the human genome, steady progress in systems biology, and advances in technology and computational sciences that offer unprecedented opportunities for benefits to human health. Much innovation and progress will still spring from and depend on creative individual investigators, but collaborative synergy will be necessary to realize many of the promises of "molecular medicine". Cooperation in project planning and execution, and sharing of data and resources are essential.

The current incentive and reward structure for academic investigators is strongly influenced by the policies of their academic institutions, their funding agencies, and the scientific journals. There is an inter-relationship among the policies of these three entities such that they can be thought of as a system, each influencing the others. The present system takes its structure from the paradigm of the single "Principal Investigator". Although this model has worked well and encourages individual creativity and productivity, it has also produced some perverse outcomes and discourages team efforts.

The National Institutes of Health (NIH) Bioengineering Consortium (BECON) was formed in 1997, in part to foster collaborations and transdisciplinary initiatives among the biological, medical, physical, engineering, and computational sciences (http://www.becon.nih.gov/becon.htm). In support of its mission, BECON organized a series of Symposia, all of which crossed traditional disciplines, and developed a Program Announcement (PA) for Bioengineering Research Partnerships (BRP's) which encourages transdisciplinary projects. Interactions with investigators involved with the Symposia, or applying for the BRP's, revealed significant hurdles to team research in the academic environment. Many of those obstacles were the result of NIH policies or procedures, others were due to academic institution practices and methods, and still others related to scientific journal guidelines and traditions. The membership of BECON decided to use its June 2003 Symposium to better understand and address these issues. These problems are not unique to biomedical engineering per se, but BECON is one of the few organizational units at NIH that crosses all Institutes and Centers and is in a position to address the issues from a trans-NIH perspective.

The Symposium: Catalyzing Team Science

The goal of the Symposium was to examine the forces encouraging and discouraging team approaches to biomedical research and to explore ways in which the NIH, academia, and others can stimulate and reward team efforts. Team science in this context includes any size team, from two investigators to hundreds. The agenda and list of participants can be found at: http://www.becon.nih.gov/symposium2003.htm.

Breakout sessions were developed around five key topics:

- NIH Policies, Procedures, and Funding Mechanisms
- Academic Institutions' Assessment and Reward Procedures
- Credit and Ownership Issues Related to Publication of Team Science
- Models of Team Science
- Institutional Administration of Research Teams

The recommendations from each of these five breakout groups can be found on the Symposium web site (URL above). Major issues and key recommendations from the Symposium are summarized in this report. Although the focus of the Symposium was on means to enhance and reward the performance of team science, this should not be construed to mean that the organizers or participants believe that team science should supplant individual-investigator research. Both modes of discovery and development are essential, and both need to be supported. This Symposium did not try to address the issue of what would be a desirable balance of support between individual and team science.

The most central recommendations of the Symposium participants are these. Team science would be enhanced if ...

NIH:

- allowed more than one Principal Investigator (PI) on individual grants;
- allowed multiple performance sites to receive appropriate indirect cost recovery;
- developed improved funding mechanisms for team science;
- gave more attention to the special review needs of team science;

academic institutions:

- developed measures of team contributor value other than PI status and authorship;
- created career paths for those who provide the infrastructure for the team;
- streamlined the administration of team science;

journals:

- specified co-authors' contributions;
- identified guarantors of article content;
- established data and materials sharing policies.

Models of Team Science

The urgency and complexity of scientific and clinical problems today often dictate the need for a team-based approach. In some cases different disciplines and/or expertise are required to solve a problem. In other cases a team forms because different approaches are required to solve a problem. For many teams the impetus is the shared need for a common facility, instrumentation or database. For certain teams the stimulus may be the intellectual challenge and potential high pay-off of a grand challenge for which a critical mass of investigators does not exist. Effective teams begin with compelling reasons for their existence, but further incentives must be built into the system to ensure full realization of their potential.

The success of team science depends on individuals who are comfortable with boundary-crossing activities. Working as part of a team seeking solutions to complex problems requires a willingness to work in an interdisciplinary environment, to collaborate with different types of organizations, and to recognize the importance of a variety of roles in the project. Educational programs that prepare students for these environments are essential as are programs to improve the quality of mentoring for those who are participants and for those who must support and evaluate team performance.

The following factors were considered essential to the success of scientific teams:

- A management structure that integrates leadership (encompassing vision, enthusiasm, commitment, and team spirit) with communication (requiring time, effort, technology, and training);
- A team-friendly environment incorporating integrity, trust, respect, and sharing;
- Institutional commitment including space, administrative support, and faculty investment.

The following guiding principals were considered likely to contribute to team success:

- Each team should be based on a central problem, a motivation that brings the team together and encourages collaboration;
- Individual creativity should be preserved while taking advantage of the synergy of team approaches;
- Team members should be selected based on team needs and not necessarily location (including the potential inclusion of non-U.S. investigators).

Research teams are variable in terms of size, location of participants, goals, and structure. Depending on size and goals, the management structure of a team may include: a Director and/or Co-directors (or Assistant or Associate Directors), Senior Manager, Other staff (as needed), Group Leaders/Team Leaders, Investigators, an internal Steering Committee, and an empowered External Advisory Board. Administrative support and budgets need attention. For small teams support may be provided by shared administrative staff. Larger teams will need full-time, dedicated, and skilled staff. PhD-level management staff can be highly effective but future career paths for such staff are uncertain. Individual budgets, core budgets and seed funds may be

needed. A support structure and mentoring for young faculty should be available. Mechanisms for individual publication and access to special resources should be developed. Plans are also needed for management of intellectual property, to deal with potential problems, to evaluate and assess progress toward goals, and to phase-out the project.

Other issues that participants and administrators of team science must think about are the impact on young investigators and their career development, the richness of the training environment vs. negative impact on graduate student and post-doctoral training, the longer lead time needed to develop a team and become productive, and the need for mechanisms to overcome cultural differences, including differences between academia and industry.

Recommendations to Funding Agencies

In reviewing research programs for support, funding agencies consider the team assembled to conduct the proposed work, but mirror the academic institutions in their focus on the role and responsibilities of the principal investigator. Credit for an award accrues to the individual named as the principal investigator. Without change at both the funding agencies and the academic institutions, those engaged in team science will be disadvantaged and the full potential of team science may fail to be realized. The award requirements of funding agencies play a large part in driving university policies. Appropriately designed policies and requests for proposals will create incentives for institutions to address the demands of team science.

NIH, in consultation with the scientific community, should change its methods by which credit is given. A paradigm shift is needed at the funding agency level. Team science would be facilitated if NIH would:

- allow for more than one principal investigator (this will require defining criteria for co-principal investigator, or comparable nomenclature such as one or more of the following suggestions -- consider using the societally-accepted concepts of partnerships or corporations where responsibility resides with more than one individual; consider a model where co-principal-investigators could self-assign level of effort; consider models where principal investigators identify an individual who is the accountable scientific coordinator and an individual who has final financial accountability for a grant; consider use of the term “Coordinating Principal Investigator”);
- develop flexible funding mechanisms for team science; develop new models for assembling and monitoring funding; increase coordination across Institutes and Centers for programs and mechanisms dealing with team science; develop mechanisms to deal with termination issues, due to lack of productivity or change in science;
- develop pilot-grant mechanisms to allow teams to form so leadership and ability to organize a team can be assessed in advance; provide supplements to grants

to support boundary-crossing activities; refine and/or establish NIH training grants to provide infrastructure support and curriculum development for interdisciplinary education; provide funds for team science grant writing.

NIH should consider changes in review for team science. The review and evaluation of team science should take into account the special features of team science, including longer lead time and interdisciplinary nature. Site visits are usually needed for large team grants. Symposium participants suggested the following:

- develop criteria to evaluate team science;
- populate study sections with members who have experience in team science, such as national laboratory investigators;
- use pre-proposals to triage applications for large team projects;
- require, as part of the application process for team science,
    1. plans to qualitatively assess contributions to science so that team members achieve due recognition,
    2. adequate staff support, including PhD-level administrator if necessary,
    3. administrative/management plan,
    4. evaluation plan (criteria for success),
    5. plan for junior faculty development,
    6. plan for intellectual property (IP) management,
    7. phase-out plan.

To further improve the climate for team science, NIH could:

- work with academic institutions to streamline the administration of team science, including subcontracting mechanisms, Institutional Review Board (IRB) policies, intellectual property policies, material transfer agreements, and conflicts of interest.
- re-examine how indirect costs are calculated and assigned, and the impact of current and proposed indirect cost procedures on team science; index grants by both terms and people; provide a unified portal for access to databases listing funded investigators.
- develop definitions of different types of teams, inventory examples of successes and failures of team science within NIH, other funding agencies, industry, etc., and post on the web.
- organize training workshops for training leaders and managers of science teams
- establish a prestigious prize for team science accomplishments.

Recommendations to Academic Institutions

The reward structures of academic institutions focus on the work of individuals. From the dissertations of graduate students to the promotion and tenure decisions for faculty, institutions are organized to evaluate the contributions and promise of individual scholars. For team science to succeed, challenges to the reward system must be addressed. The first challenge is to recognize not only the contributions of individuals but also the interdependence of team members. The success of a team is more than the simple sum of its parts, and mechanisms for recognition need to take into account both individual and team performance. The scientific expertise necessary for the success of a team project is distributed among team members. As stated previously, the leadership of teams may not reside in a single individual as the "principal investigator" model implies. Successful teams may share leadership in complex ways.

The structure of teams is varied but a common theme is the growth of a class of highly skilled team members whose expertise is part of the essential infrastructure of a project but for whom no clear academic career path exists. These key team members may be advanced postdoctoral scholars, non-tenure track faculty, or technical staff. The transition from trainee to team scientist is ill-defined and may be marked by an absence of institutional commitment. Team members may contribute significantly to the development of technical advances but may not see their contributions reflected in the kind of publication record expected of faculty in research institutions. Better measures of contributions are needed as well as mentoring of team members.

While not all teams are large, the management of large teams creates administrative and coordination demands that exceed the burdens on smaller and less complex programs. Team programs may cut across institutional and geographic boundaries. Subcontracting, transferring materials, meeting the requirements of Intuitional Review Boards and conflict of interest reviews, and negotiating intellectual property rights with multiple organizations is time- and resource-consuming. Funding large team projects without adequate administrative support or streamlining of processes and policies threatens the success of projects.

To better stimulate and reward team science, academic institutions could:

- develop tools to assess and reward the merit and productivity of individuals involved in team science—e.g., research portfolios, annual reviews, reports from external advisory committees, promotion and tenure committees, and expenditure credit;
- develop mechanisms to give credit when investigators work in non-traditional modes;
- develop tools to assess, reward, and improve the quality of mentoring at all levels (e.g., deans, chairs, senior faculty, and external advisory committees);
- establish career pathways to recognize and reward project managers and those who enable team science (e.g., research faculty and technical support personnel);

- build systems to track co-principal-investigator credits;
- work to align incentives equitably between the team and the individual;
- work with NIH to streamline the administration of team science, including subcontracting mechanisms, Institutional Review Board (IRB) procedures, intellectual property policies, material transfer agreements, and conflicts of interest policies;
- develop mechanisms for reciprocity of IRB procedures;
- make technology transfer department personnel an integral part of research teams;
- encourage the use of simple default models for intellectual property ownership, licensing responsibility, and revenue-sharing;
- establish partnerships with minority serving institutions and other potential contributors to research teams (e.g., industry, undergraduate institutions, and community colleges);
- clearly state their policies and processes regarding post-publication dissemination of research materials or data to competing investigators.

Academic professional organizations could:

- make efforts to educate top leadership about the barriers and needs for performing team science;
- develop a handbook of good practices for promoting and assessing individual and team performance;
- sponsor a workshop to discuss bookkeeping problems associated with team science.

Recommendations Regarding Credit, Ownership, and Dissemination Issues

Team membership can make it hard to obtain due public recognition of achievement. For example, employers and appointments and tenure committees pay a great deal of attention to publications of individuals and the journals in which they appear, but sometimes this occurs in a simplistic fashion. This can prejudice the process against team members whose names may not appear in prominent parts of the authorship lists if at all, or who for one reason or another miss opportunities to publish work that is essential to a project and of high scientific quality but of low impact. Furthermore, publications and patents can be delayed if issues of allocation of credit and intellectual property rights have not been resolved at an early stage. It is in everyone's interests for project leaders, journals editors and funding agencies to develop better means of indicating credit where it is due and minimizing obstacles to dissemination.

Journals could help with appropriate assignment of credit for and dissemination of team research results by:

- requiring that co-authors specify their contribution to an article and requiring that this be published;

- requiring that one or more of the authors act as guarantor(s) and take public responsibility for the content of an article, and then publishing this with the contributions list in the journal;
- facilitating communication among editors and reviewers, and editorial teams where appropriate, when considering “team science” articles to ensure fair and appropriate breadth of review;
- **c**learly stating data and materials sharing policies, and the consequences of noncompliance.

Manuscripts reporting team research could be improved if authors would:

- refer to the Vancouver group’s recommended criteria for authorship (http://www.icmje.org/) when there is uncertainty over who should be an author;
- when pursuing general publications for the team, also encourage team members to publish their contributions in specialized journals, or otherwise insure that their individual contributions are made explicit in the open literature;
- avoid field-specific jargon whenever possible;
- keep the audience in mind and find a medium between too technical and too general;
- show papers to colleagues in other fields before submission;
- contact editors at an early stage if manuscripts are expected to make unusual demands on a journal;
- make decisions on intellectual property rights early in the development of an article so that there is no delay in dissemination (which occurs if IP issues are not addressed promptly and thoroughly);
- acknowledge the source of shared data and materials.

NIH (and other funding agencies) could aid in these credit and dissemination issues by:

- endorsing, as a statement of good practice, the policy that journals should require that co-authors specify their contribution to an article;
- assisting in the development of solutions (e.g., publicly-available databases) for the deposition of data and technical developments and making these solutions citable;
- supporting the principal for sharing integral data and materials expeditiously (UPSIDE) on publication (http://www.nap.edu/books/0309088593/html/);
- making authors’ lists in articles contributed by consortia searchable in Medline.

Conclusion

The factors that govern incentives and rewards in the system for academic investigators are multiple and complex. Change is needed in all three key components of that system, namely the NIH, academic institutions and scientific publications.

NIH can effect change by modifying some rules and regulations, and by using its "bully pulpit" position to influence desired changes within Universities. Universities are responsive to funding agency programs and policies. NIH could do this by:

- allowing for more than one principal investigator on individual grants;
- allowing multiple performance sites to receive appropriate indirect cost recovery;
- developing more flexible funding mechanisms for team science;
- accommodating the special review needs of team science;
- increasing coordination across Institutes and Centers for programs and mechanisms dealing with team science;
- expanding research training support for interdisciplinary education;
- inventorying examples of successes and failures of team science, and developing a primer for team science on the Internet;
- establishing a prestigious prize for team science accomplishments.

Promotion and tenure decisions at universities are dictated by institutional criteria, but also by the beliefs of faculty members on the promotions and tenure committees. Academic institutions could foster team science by:

- developing measures of team contributor value other than PI status and authorship;
- creating career paths for those who provide the infrastructure for the team;
- working with NIH to streamline the administration of team science, to adequately fund the additional administrative burdens that large teams incur, and to seed the development of scientists who are comfortable with boundary crossing activities.

Assigning credit for the results of team efforts is extremely challenging. Authorship on scientific publications plays a central role in distributing recognition. Journals could advance team efforts by:

- specifying co-authors' contributions;
- identifying guarantors of article content;
- establishing data and materials sharing policies.

Afterword

During the period of time that BECON was planning its 2003 Symposium there were some parallel efforts relevant to NIH policies or procedures that came to similar conclusions. In May 2002, Elias A. Zerhouni, M.D, Director of the NIH, initiated a process to chart a "roadmap" for medical research in the 21st century (http://nihroadmap.nih.gov). The purpose was to identify major opportunities and gaps in biomedical research that no single institute at NIH could tackle alone but that the agency as a whole must address to make the biggest impact on the progress of medical research. One of the themes that emerged from the NIH roadmap process was the need to stimulate interdisciplinary research teams.

Also during 2002 the Institute of Medicine (IOM) supported two committees that addressed issues related to the BECON symposium in their subsequent reports. The National Cancer Policy Board (one of the boards of the IOM) charged an ad hoc committee to look at the role of large-scale projects in the biomedical sciences, identify obstacles to the implementation of these projects, and make recommendations to improve the process. Its report entitled *Large-Scale Biomedical Science: Exploring Strategies for Research* was published June 19, 2003 (http://www.iom.edu/report.asp?id=12642). The recommendations are intended to facilitate a more open, inclusive, and accountable approach to large-scale biomedical research, which in turn will maximize progress in understanding and controlling human disease. Simultaneously the IOM charged a committee to study the organization of NIH. That committee's report entitled *Enhancing the Vitality of the National Institutes of Health: Organizational Change to Meet New Challenges* was published July 29, 2003 (http://www.iom.edu/report.asp?id=14300). The report calls on NIH to foster interdisciplinary research, development and training.

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